Building Michigan's Leadership in Economic Development Around Products of Green Chemistry: An Action Plan for Michigan Green Chemistry Research, Development and Education

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Introduction

In October 2006, Governor Jennifer M. Granholm issued Executive Directive No. 2007-6 (Directive), "Promotion of Green Chemistry for Sustainable Economic Development and Protection of Public Health." The Directive establishes state policy encouraging the use of safer, less toxic, or non-toxic chemical alternatives to hazardous substances and the research, development, and implementation of Green Chemistry in Michigan.

Green Chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. It therefore holds promise to protect the public health and general welfare of the people of Michigan and its environment, while promoting sustainable economic development. By vigorously promoting a new Green Chemistry strategy, the State of Michigan can develop and strengthen its economy, protect its environment and enhance the quality of life for all of its citizens.

The Executive Directive tasks the Department of Environmental Quality (DEQ) with coordinating implementation and promotion of a Green Chemistry Support Program for sustainable economic development and protection of public health. As part of the Green Chemistry Support Program, the DEQ is to convene a Green Chemistry Support Roundtable that is representative of public health, industrial, environmental, local government, and general public perspectives. The Roundtable is to advise the DEQ on how best to carry-out the work of the Green Chemistry Support Program that concentrates on:

1. Providing encouragement for Green Chemistry research, development, demonstration, education, and technology transfer.
2. Examining methods by which state government can create incentives for consideration and use of Green Chemistry processes and products.
3. Facilitating the adoption of Green Chemistry innovations in Michigan.
4. Expanding education and training of undergraduate and graduate students, and professional chemists and chemical engineers in Michigan, including through partnerships with industry, in Green Chemistry science and engineering.
5. Collecting and disseminate information on Green Chemistry research, development, and technology transfer.
6. Providing venues for outreach and dissemination of Green Chemistry advances such as symposia, forums, conferences, and written materials in collaboration with, as appropriate, industry, academia, scientific and professional societies, and other relevant groups.
7. Supporting economic, legal, and other appropriate social science research to identify barriers to commercialization and methods to advance commercialization of Green Chemistry.

8. Providing for public input and outreach to be integrated into the Green Chemistry Support Program by the convening of public discussions, through mechanisms such as citizen panels, consensus conferences, and educational events.
9. Promoting voluntary, cooperative efforts with industrial sectors to develop Green Chemistry plans.
10. Making recommendations to the Governor on an annual basis for a Governor's Green Chemistry Award, promoting excellence, innovation, economic development and public health risk reduction by businesses and institutions.
11. Maintaining a website to provide information about the Green Chemistry Support Program.

Methodology

The action plan that follows has been developed by the Lowell Center for Sustainable Production to assist Michigan in implementing its Green Chemistry Support Program. Information for the action plan has been gathered from:

- A Green Chemistry Stakeholders meeting on December 12, 2007, hosted by the Department of Environmental Quality (DEQ). Over 40 stakeholders, representing environmental groups, industry, and educators, took park in this day long meeting. The group discussed program priorities, partnering opportunities, and formation of the Green Chemistry Roundtable.
- Interviews in January and February 2008 with leaders in the field of Green Chemistry.
- Interviews with 15 participants of the Green Chemistry Stakeholders meeting and other key stakeholders, during February and March 2008.
- The Lowell Center for Sustainable Production's fifteen years of experience working with government, businesses and communities in studying and promoting safer forms of production.

Action Plan Summary

To implement its Green Chemistry action plan, the State of Michigan must partner with its business community, its educational institutions, and its environmental and health advocacy organizations to advance Green Chemistry leadership in the state. It must move forward to strengthen and reward those businesses wanting to invest in and apply Green Chemistry and products of Green Chemistry; establish conditions for Green Chemistry to thrive; integrate Green Chemistry and engineering into its education curriculum; and raise public awareness and enthusiasm for a "New Green chemistry Economy".

The action plan detailed in this report lays out three phases of development over the next five years.

Phase One (1-12 months)
Building Awareness

Green Chemistry is not well known or understood by the general public, businesses and academics alike. Phase One will educate and build awareness of Green Chemistry by illustrating successes in Green Chemistry that benefit public health and welfare, the environment and the economy. This critical phase will focus on building a base for Green Chemistry in Michigan, including establishing strong linkages with economic development efforts, and will:

- Define the parameters of the Green Chemistry Support Program;
- Build a resource database of Green Chemistry in the state; and
- Create a Green Chemistry "brand".

Phase Two (12-36 months)
Building the Program

Having defined the parameters of the Green Chemistry Support Program, built a resource database, and created a brand and leadership, Phase Two will build on Green Chemistry successes that emerge from Phase One by building a program, establishing Michigan's leadership role in Green Chemistry. A key aspect of this part of the project is to make clear the links between Green Chemistry and economic opportunity for the state. During this phase, the state will:

- Hold a Green Chemistry Research and Education Conference;
- Develop an Annual Green Chemistry Awards Program; and
- Set the groundwork for long term Green Chemistry efforts that will benefit Michigan's economy, environment, and health.

Phase Three (3-5 years)
Building the Future

The implementation of longer-term projects that are the focus of the third phase (3-5 years) have been researched and developed in the preceding years.

These longer-term projects are geared towards building Michigan's Green Chemistry future. This phase will:

- **Establish opportunities for sustainable adoption of Green Chemistry within education;**
- **Implement new innovative technology directions; and**
- **Establish a Green Chemistry Innovation Center and regional nodes.**

Action Plan

The Lowell Center for Sustainable Production has developed this action plan to assist Michigan in implementing its Green Chemistry Support Program as outlined in Governor Jennifer M. Granholm's Executive Directive No. 2007-6 (Directive), "Promotion of Green Chemistry for Sustainable Economic Development and Protection of Public Health" from October 2006. The Directive establishes state policy encouraging the use of safer, less toxic, or non-toxic chemical alternatives to hazardous substances and the research, development, and implementation of Green Chemistry in Michigan.

This draft action plan lays out three phases of development over the next five years: Phase One (1-12 months), *Building Awareness;* Phase Two (12-36 months), *Building the Program;* and Phase Three (3-5 years), *Building the Future.* Each of these three phases implements three key action items. The goal of these actions is to make Michigan a leader in Green Chemistry education, research and application.

Application of some elements in the 3-5 year period will require additional funding; however, progress should be made as soon as possible in developing specific activities under those elements.

Phase One (1-12 months), *Building Awareness,* key action items:

- Define the parameters of the Green Chemistry Support Program;
- Build a resource database of Green Chemistry in the state; and
- Create a Green Chemistry "brand".

Phase Two (12-36 months), *Building the Program,* key action items:

- Hold a Green Chemistry Research and Education Conference;
- Develop an Annual Green Chemistry Awards Program; and
- Set the groundwork for long term Green Chemistry efforts that will benefit Michigan's economy, environment and health.

Phase Three (3-5 years), *Building the Future,* key action items:

- Establish opportunities for sustainable adoption of Green Chemistry within education;
- Implement new innovative technology directions; and
- Establish a Green Chemistry Innovation Center and regional nodes.

All of these action items are crucial to the success of Green Chemistry in Michigan but it is likely that some will take longer to implement than others. Incorporating Green Chemistry into the educational curriculums for example will take longer than developing a conference or a Green Chemistry Awards Program. Further, the longer term elements will depend on interests and needs identified in the earlier years of the Support Program. However progress in advancing all action items needs to be made immediately for their success. All action items need the dedication of working subgroups of the

Green Chemistry Roundtable from the initial implementation of this action plan. Two critical aspects of this action plan are to create ownership and leadership within the Green Chemistry Support Program and Green Chemistry efforts within the state. Such ownership, particularly of the Roundtable, is critical to the long term success and viability of the Program.

Finally, specific action items, particularly those under years 3-5 will require a significant infusion of additional funding. However, action should be taken as soon as possible to develop plans for implementing specific action items. Clearly, raising additional resources for the implementation of longer term action items and the sustainability of the program should occur.

Phase One (1-12 months)

Building Awareness

This initial and critical phase will build a base of Green Chemistry in Michigan. This phase could be called the "quick start" phase where momentum and excitement are generated while base building for longer term activities is initiated. Currently, Green Chemistry is not well known or understood, there is uncertainty as to what researchers and companies are working on or teaching in Green Chemistry, and there are no mechanisms to communicate Green Chemistry efforts to others. Hence Michigan's Green Chemistry success stories are lost. Through the objectives laid out in the first phase, awareness of and knowledge about Green Chemistry will be built, in addition to identification and networking of Green Chemistry practitioners in the state. Success stories will speak for themselves in illustrating the benefits of Green Chemistry for public health and welfare, the environment and the economy.

This phase includes the establishment of the Roundtable subgroups that will implement the key action items in Phase Two and Three so that capacity can be built and timelines met for those phases as well. While the Michigan DEQ ultimately has responsibility for implementing the Support Program, it is important that these Roundtable subgroups take ownership in developing ideas, making recommendation, and supporting implementation of tasks identified in this action plan.

Objectives of Phase One:

- Define the parameters of the Green Chemistry Support Program;
- Build a resource database of Green Chemistry in the state; and
- Create a Green Chemistry "brand".

Define the parameters of the Green Chemistry Support Program

Action 1:
A subgroup of the Roundtable is established to clarify criteria for defining the activities of Green Chemistry and to provide boundaries for the Support Program so it can be more focused. This will then guide the research, development, application and education efforts.

There is a lot of discussion about what Green Chemistry is and is not. To ensure a consistent message is given, boundaries to the Support Program should be provided and criteria and guidelines developed. These would then form the basis of all research, development, application and education projects.

The Executive Directive states clearly that "Green Chemistry means chemistry and chemical engineering to design chemical products and processes that reduce or eliminate the use or generation of hazardous substances while producing high quality products through safe and efficient manufacturing processes." It also states the 12 principles upon which Green Chemistry is based.

However, some of the areas require further clarification:

- Green Chemists think of Green Chemistry as a continuous process so guidelines / criteria need to be developed to help define whether a product and / or process is supportive of Green Chemistry. It needs to provide guidance for questions such as, "If a product is produced that is more energy efficient but still uses hazardous substances, should this be used as an example of Green Chemistry?" Such criteria will help support decisions in research, procurement, incentives, and awards for Green Chemistry.
- There seems to be a lot of crossover between Green Chemistry and Sustainable Chemistry (or Green Engineering and Sustainable Engineering). In order to determine what falls within the scope of this Support Program, clarity needs to be provided about what each of these are and how they are different, and what the boundaries of this Support Program are.

Build a resource database of Green Chemistry in the State

Action 2:
One of Michigan's Universities or a well established business support organization working on sustainable business is given a grant to conduct research and outreach in order to compile a resource portal or database of Green Chemistry efforts within Michigan, including case studies of success stories. A brochure based on this research, "Michigan's Green Chemistry Future" will be developed. Both will be available within six months.

Compiling and analyzing Michigan's existing Green Chemistry resources has a two fold goal. The first is to compile information on Michigan's Green Chemistry efforts into a single portal, capturing the Green Chemistry research, development, application and education efforts underway in Michigan, and the resulting success stories. These efforts currently exist within a company or a university etc., but they are not often known outside that particular institution. This information can be gathered, characterized and compiled into a Green Chemistry resource database that will be available within six months. Although the focus of the resource database is to capture information specific

to Michigan, national efforts should also be captured so they too can be utilized. The resource database will be publicly available and accessible; the success stories will illustrate Green Chemistry's benefits to public health and welfare, the environment and the economy. Results from this research will be publicized through a brochure, "Michigan's Green Chemistry Future." The resource database and brochure will be the first products of the Green Chemistry Support Program.

The second goal is that the data collection process begins an outreach process, helping to establish a Green Chemistry practitioners network in Michigan. It will identify ***leaders and champions*** in Green Chemistry and their efforts will be publicized. These leaders will be crucial to the future implementation of the program. This outreach process will be the initial step towards a Green Chemistry Research and Education Conference in the first two years of the Support Program.

Initial research categories for the database should include but not be limited to Green Chemistry research and development, applications, education, capital resources, funding, professional organizations, trade associations, consulting firms, advocates and agencies.

Create a Green Chemistry "brand"

Action 3:
A subgroup of the Roundtable is established to develop Michigan's Green Chemistry brand. This will include a strategy and tactical plan to achieve the objectives aligned with the brand, a set of metrics to track its progress and measure its success, and an event launching the brand.

Michigan is the home of many industries that characterize early industrial development, and the use of the Great Lakes resources brought wealth and well being to the region. However, the full cost of the concentration of industry and people on the Great Lakes ecosystem is only now being understood. A brand can be developed for Michigan that links the preservation of Michigan's beauty, notably its Great Lakes, with its desire for economic growth through Green Chemistry e.g. "Green Chemistry is the road to a blue and prosperous Michigan", or "Green Chemistry for a blue Michigan." This brand can be used throughout the state as a slogan on billboards, economic development outreach materials, on license plates, etc. It will help develop a buzz about Green Chemistry and establish Green Chemistry as an economic development strategy. The Green Chemistry brand should also be highlighted as part of a media strategy, including coverage of Green Chemistry events and op-eds. In addition, an event launching the Green Chemistry Support Program should be held in the early summer of 2008. Governor Granholm should officiate over the event held at the state capital, "Michigan's Green Chemistry Future;" where there would be two short keynote speakers and everyone would be asked to wear a green item. This would be a highly publicized event. The Green Chemistry buzz would then be officially launched.

Once the brand is established, a strategy and tactical plan to achieve objectives aligned with the brand needs to be developed. For example, a goal such as achieving a non-toxic environment could be established and metrics to measure successes in Green Chemistry to achieve that goal can be developed. This requires establishing a baseline, end goals, and interim targets. Other goals could be developed around waste reduction, greenhouse gas reductions through Green Chemistry, development of new products of Green Chemistry, etc.

In order to track progress and measure the success of our strategy, a set of metrics needs to be developed based on the strategy's objectives. Metrics will include but not be limited to environmental, economic and health and safety measurements. They will likely be specific e.g. the target for the first year is that 5-10 businesses seek Green Chemistry technical assistance; or that x number of companies in Michigan change to Green Chemistry processes.

Phase Two (12-36 months)

Building the Program

Phase Two will build on the resource database, brand, network and initial leadership created in Phase One to begin establishing Michigan as a leader in Green Chemistry. Starting with the success stories collected and the Green Chemistry champions and leaders that emerge, the focus of this phase will be to bring greater awareness and education regarding Green Chemistry to a wide audience while celebrating Green Chemistry successes in the state.

Objectives of Phase Two:

- Hold a Green Chemistry Research and Education Conference;
- Develop an Annual Green Chemistry Awards Program; and
- Set the groundwork for long term Green Chemistry efforts that will benefit Michigan's economy, environment and health.

Hold a Green Chemistry Research and Education Conference

Action 4:
A Green Chemistry Research and Education Conference are held between 12-18 months after the action plan is implemented. A subgroup of the Roundtable is established to plan and prepare for the conference.

A multi-stakeholder conference is an excellent way to educate a wide audience about the benefits of Green Chemistry; establish a venue for sharing successes, barriers, and strategies; maintaining the Green Chemistry buzz; and developing an on-going network to advance the Support Program's implementation. The focus of the conference will be to highlight success stories uncovered in the development of the Green Chemistry resource database and create opportunities for networking and leadership. Its objectives are to illustrate and promote research, development and application initiatives; understand barriers and opportunities; and to demonstrate the economic and health and environmental benefits of Green

Chemistry. Significant outreach and marketing work will be needed as those attending will need to know how they and their business / organization will benefit from attending.

Specifically, the conference will:

- Build, engage, and network Green Chemistry champions and leaders
- Engage a range of businesses in learning about the economic benefits of Green Chemistry and how to overcome barriers
- Showcase innovative Green Chemistry research within industry, academia, and the community
- Provide an opportunity for educators of different levels to engage in dialog about building capacity and curriculum in Green Chemistry education
- Be an opportunity to introduce Michigan's brand of Green Chemistry, it's objectives and metrics

The Roundtable subgroup may want to consider dividing the conference into two sections: one focused on education, where teachers and students can present research and educational efforts; and one focused on research, development and application. At any rate, it is important to view this as an integrated conference.

The conference will have not just clear objectives, but also clear outcomes and follow up to build on the momentum the conference will generate.

Develop an Annual Green Chemistry Awards Program

Action 5:
A subgroup of the Roundtable is established to develop an annual Green Chemistry Awards Program. The first awards ceremony will be held at the Green Chemistry Research and Education Conference.

The annual Presidential Green Chemistry Awards Program is a good illustration of the interest and buzz that an awards program can generate around Green Chemistry. Hundreds of companies and researchers now compete annually for recognition of their efforts in Green Chemistry and the database of applications has become an important source of information on Green Chemistry efforts and education. Formal acknowledgement of the Green Chemistry efforts in Michigan through an awards program will serve the same purpose.

The Michigan Awards Program should endeavor to garner both wide participation and a wide audience within Michigan so the initial awards ceremony should be held at the Green Chemistry Research and Education Conference. The award categories will also be broader than those in the Presidential Green Chemistry Awards Program to capture this wider audience.

Companies and organizations should self-nominate for awards, and an objective review panel should review applications. All awards must illustrate

how they support Michigan's growth; how the innovation will be advanced; and its economic, environmental and health benefits. The Roundtable subgroup should develop criteria for awards and a consistent review process.

The suggested award categories are:

- Manufacturing / industrial applications that recognize individual efforts, team efforts, corporation efforts;
- Academic research and development efforts;
- Educational reform efforts e.g. recognizing Green Chemistry elements that have been added to a curriculum; Green Chemistry certifications, etc.; and
- Community reform that recognizes efforts from advocates, local government, service organizations and the general public.

As a starting point for the first awards, past Michigan nominees to the Presidential Green Chemistry Awards should be invited to submit applications for awards. The awards ceremony should be an important media event, held with state government leadership.

Set the groundwork for long term Green Chemistry efforts that will benefit Michigan's economy, environment and health

Action 6:
A subgroup of the Roundtable is established to explore and make decisions about longer term directions that will benefit Michigan in Green Chemistry, building and consolidating existing capacity within and outside the State.

Building on the Green Chemistry resource database, networking efforts, and the Green Chemistry Research and Education Conference a number of potential directions for Green Chemistry innovation and education will present themselves. Decisions will need to be made about which directions to pursue and, importantly, how to finance them. Existing capacity within and outside the State can and should be built on and consolidated to help frame these decisions. An ultimate goal of this action is to establish capacity that will ensure the long term viability of the Support Program and Green Chemistry successes in the state. These next steps focus on education capacity building; financial capacity building; professional organization capacity building, and government capacity building.

Education Capacity Building

There are a number of academics teaching and conducting research on Green Chemistry in Michigan, some who have received Presidential Green Chemistry Awards. However, none of these individuals have emerged as leaders in the field either at the state or federal level. It is critical that Green Chemistry academic champions emerge and that efforts are made to ensure the training and mentoring of leaders in the future. There are a number of existing directions that could help this process:

- Green Chemistry Education Networks. Michigan should establish a Green Chemistry education network to link teachers at different levels to share curriculum, training tools, and strategies. Two models for such a network are:
  - The Green Chemistry Education Network (GCEdNet) www.gcednet.org facilitated by the University of Oregon's Department of Chemistry. The GCEdNet have offered to help set up a node of the network in Michigan. A Google map of individuals interested in Green Chemistry http://greenchem.uoregon.edu/Pages/MapDisplay.php has been produced which could form the basis of a Michigan Green Chemistry Education Network.
  - The New England Association of Chemistry Teachers (NEACT) - http://www.neact.org/
- Chemistry in Education Workshops (GCEW). Michigan should establish summer training programs in Green Chemistry education. A goal of such trainings and any educational activity is to "train the trainer" so that impacts can be multiplied. As a model, the University of Oregon's Department of Chemistry holds Green Chemistry in Education Workshops (GCEW) http://chemistry.gsu.edu/CWCS/green.php over the summer for faculty. These enabling workshops train chemical educators who can implement Green Chemistry in the classroom. This has helped to produce educational materials that can be incorporated into a Green Chemistry curriculum. This is known as the Green Chemistry Education Database http://greenchem.uoregon.edu/gems.html

Financial Capacity Building

Establishing financial resources for the ongoing implementation of the Green Chemistry executive directive is essential to its long term success. Making a clear link between Green Chemistry and economic development and competitiveness for the state will strengthen the position of the Program as both an economic and environmental health initiative. A first step may be to commission a study on the economic development opportunities in Green Chemistry and bio-based materials and fuels, demonstrating both economic growth potential, potential private and public state and federal funding sources, and outlining a menu of possible incentives to advance Green Chemistry research, development, and adoption in the state. Such incentives could include tax incentives, access to low income loans or low cost space, preferential purchasing treatment, support in securing venture capital funds, etc. Such incentives packages are already being developed in the renewable energy field. Financial capacity building could take many directions including:

- The New Economy Initiative for Southeast Michigan has recently been established by 10 foundations contributing $1 million each. Grants will be given to support the efforts of nonprofit organizations and governing

agencies to transform the economy of southeast Michigan and return prosperity to the region. http://www.neweconomyinitiative.org/index.php?option=com_content&task=view&id=18&Itemid=32

- Michigan's Economic Development Corporation (MEDC) 21st Century Jobs Fund will invest more than $2 billion in new technologies that will drive Michigan's economy into the future. Four key growth areas have been identified that have potential areas of collaboration and synergy with Green Chemistry efforts: life sciences, advanced manufacturing, alternative energy, and homeland security. Possible areas of collaboration are:
  - Criteria are added to the selection of 21st Century Jobs Fund grantees that would give priority to Green Chemistry innovation.
  - The 21st Century Jobs Fund Incentive packages are used as models to attract businesses for Green Chemistry research, development and application.
- The capital resources of companies who have left the state could be Green Chemistry resources. Prime examples are Pfizer's facilities in Holland and Ann Arbor. One of Michigan's state universities has opportunities to utilize the Holland facility and Spark of Ann Arbor (an agency that seeks to advance the economic development of innovation-based businesses in the Ann Arbor area) is facilitating the utilization of the Ann Arbor facility. Collaboration with facilitators of these facilities could provide capital resource opportunities for Green Chemistry innovation research and technology.
- State and private universities may be willing to provide capital, in-kind or matching grant support for implementation of aspects of the Green Chemistry Support Program. For example, there are numerous sustainability centers, some of which are endowed, at universities in the state.
- Michigan's renaissance zones, economic development zones, administered by the Michigan Economic Development Corporation, which provide tax incentives for companies locating within their borders. Such benefits could be used to establish Green Chemistry "eco-industrial parks" co-located with educational institutions such as community colleges.

Professional and Business Organization Capacity Building

Numerous active professional and business organizations exist in Michigan with collaborative opportunities for the Green Chemistry Support Program. These organizations should be engaged in promoting the program; engaging in research and outreach (for example training of professional chemists on Green Chemistry tools); undertaking supply chain discussions on Green Chemistry application in conjunction with government authorities; hosting member conferences on Green Chemistry; etc. Some examples of these professional and business organizations include:

- The four Sustainability Roundtables in the state, the most active of which is in West Michigan. These are facilitated by the Sustainable Research Group.
- Sustainable Manufacturing User groups, facilitated by the Sustainable Research Group.
- The Suppliers Partnership for the Environment, an innovative partnership between automobile original equipment manufacturers and their suppliers and the Environmental Protection Agency (EPA). http://www.supplierspartnership.org/
- The Green Suppliers Network, facilitated by the USEPA.
- The Manufacturing Association.
- American Chemical Society chapters.
- Regional Economic Development Councils.
- Manufacturing Extension Partnerships.

Government Capacity Building

Michigan has an active pollution prevention outreach program in its Department of Environmental Quality. The resources and contacts established for this effort should be applied to Green Chemistry support. Further, Michigan should take leadership in Green Chemistry Promotion through state procurement efforts. There are numerous options for state government capacity building, including:

- DEQ could initiate industry sector and supply dialogs on Green Chemistry and safer alternatives to stimulate information and technology, and experience sharing. For example, as a result of requirements under the European Union's Restrictions on Hazardous Substances Directive, the Massachusetts Toxics Use Reduction Institute has established a wire and cable dialog to explore alternatives to lead, some flame retardants and other chemicals of concern.
- DEQ could establish a demonstration sites program to highlight promising new Green Chemistry technologies with the potential for broad application.
- DEQ could develop fact sheets on Green Chemistry success stories as well as on substances of concern and Green Chemistry alternatives.
- DEQ could train state technical assistance professionals (manufacturing extension, pollution prevention technical support) in promising Green Chemistry / biomaterial innovations to diffuse to businesses.
- DEQ could consider including Green Chemistry innovations as part of Supplemental Environmental Projects (in response to violations) to encourage / fund education or implement Green Chemistry projects.
- The state could develop a Green Chemistry and bio-based materials and fuels procurement program to ensure these are prioritized in state purchasing.

- DEQ could undertake training for advocates, communities and workers on Green Chemistry and tools for its application in practice.

Phase Three (3-5 years)

Building the Future

Phase Three is focused on long term projects that bring economic and intellectual wealth to Michigan as well as new jobs in sustainable industries. The development of long term goals go hand in hand with the resource database development and groundwork setting of Phases One and Two respectively. The long term projects ultimately selected have been researched and developed in the preceding years and will further solidify Green Chemistry efforts in Michigan:

Objectives of Phase Three:

- Establish opportunities for sustainable adoption of Green Chemistry within education;
- Implement new innovative technology directions; and
- Establish a Green Chemistry Innovation Center and regional nodes.

Establish opportunities for sustainable adoption of Green Chemistry within education

Action 7:
A subgroup of the Roundtable, working with the Michigan Education Association and academic institutions will establish a long term education strategy and programs that ensure Green Chemistry is incorporated into science and chemistry education from k-12 through the university level.

As discussed earlier, Green Chemistry is not well known or understood and environmental concerns are not an integral part of chemistry education at this point in time. Therefore Green Chemistry education is relevant for K-12, within universities, within industry and with the general public. A Green Chemistry education strategy and programs must take into account all of these levels of education.

K-12

A new generation of leaders in Green Chemistry is essential to ensuring the long term adoption and transition to safer chemistry. As such, educational efforts must begin with changes within existing curricula for K-12. Links can be made between chemistry and environmental science (including toxicity and human health). It is important for children to start to understand the benefits and potential health effects of chemistry, and that chemistry must be considered in the context of health and environment. There is a need for modification of curricula and laboratories that can help educate students on the benefits of chemistry and the design of benign molecules. Some of this work has begun through the Green Chemistry Education Database.

Universities

As faculty in many universities and community colleges have expressed an interest in Green Chemistry, a first step towards building Green Chemistry into university education should be a meeting of major universities and community colleges to discuss a long term Green Chemistry education program that benefits all institutions and reduces the funding competition between them. Specific projects that can be implemented through such a program are:

- Grant one year Green Chemistry assistantships / fellowships to undergraduate students. The students would work within a company on a Green Chemistry application that will directly benefit Michigan.
- Fund sabbatical semesters for faculty at Universities with established Green Chemistry programs e.g. Carnegie Mellon or University of Oregon
- Fund faculty community colleges and universities to attend Green Chemistry trainings/conferences.
- Offer scholarships for students in Green Chemistry who can make a strong case for its application.

Industry

The most important education for industry is demonstration and application. ½ day or 1 day symposiums demonstrating actual innovations / research could be set up regularly to keep sectors abreast of new innovations. These symposia would need to be organized in collaboration with groups conducting education within their own sectors e.g. sustainable manufacturing user groups, sustainable roundtables, trade associations, and professional associations. Further, continuing education / training courses for industry chemists / scientists could be developed to provide education on Green Chemistry research and development tools.

Public

Educating the public would begin with the Michigan Green Chemistry brand which would establish information on the solutions Green Chemistry provides. Specific suggestions to further educate the public include:

- Seminars and / or seminar series within universities or Museums of Science called "Green Chemistry Saturdays". Students of Green Chemistry within universities would be required to teach the public at conferences or Green Chemistry days with hands on activities.
- The Detroit Science Center (or other science museums in the state) could house an interactive Green Chemistry display.
- Existing environmental festivals, such as earth day fairs could be utilized to provide education on Green Chemistry.
- DEQ or other stakeholders could write op-eds or news articles in state newspapers or other media on Green Chemistry successes in the state.

Implement new innovative technology directions

Action 8:
A subgroup of the Roundtable will be established to develop a strategy for implementing long term projects that illustrate growth areas of innovative Green Chemistry technologies, and provide economic benefit to Michigan.

This activity could be considered catalyzing of Green Chemistry research and development, and adoption investments. Developing and implementing growth area investments in innovative Green Chemistry technologies is key to establishing Green Chemistry's long term success in Michigan. These will illustrate Green Chemistry's potential and be "showcase" projects. A model for such investment is the Signature Research Center Initiatives program, established by the state Economic and Community Development Division in Oregon. These establish investments in three Signature Research Centers committed to accelerating the commercialization of cutting-edge research and facilitating public-private partnerships that anchor next generation industries in Oregon.

Some research directions in Michigan that could be considered include:

- Biomass conversion. Currently there are 5 corn ethanol plants in Michigan that only produce ethanol. It is possible for these plants to go beyond producing ethanol and produce co-products like polylactic acid (PLA). This would require additional investment to further refine PLA and other specialty chemicals.
- Synthetic fabric in office furniture industry. Biodegradable PLA fabric is being used in some office furniture. This has wide implications for home and auto furnishings sectors that are already strongly established in Michigan.
- Water based paints in the auto industry. Water based paints developed to spray on automobiles could have wide implications for Michigan's whole auto sector.

Establish a Green Chemistry Innovation Center and regional nodes

Action 9:
A subgroup of the Roundtable is established to develop a Green Chemistry Innovation Center and regional nodes to serve as the focal point of Green Chemistry activities in Michigan.

Within three to five years, the state should establish a Green Chemistry Innovation Center and regional nodes to play a coordinating, facilitating, supporting and promotional role for Green Chemistry in Michigan. In essence, these centers would carry out the action items previously identified in a more coordinated fashion. To accommodate Michigan's geography and regional differences in industry, a center could be established in the Detroit area, with two satellite centers in Lansing and Grand Rapids. Models for such centers include the Massachusetts Toxics Use Reduction Institute and the New York Pollution Prevention Center. These centers will:

- Be the focal points of all Green Chemistry activities in Michigan.
- Coordinate all Green Chemistry outreach activities and events.
- Coordinate educational resources, including Green Chemistry training.
- Conduct on-site educational training to the general public and school children. Green Chemistry students at universities will conduct these trainings.
- Support and catalyze research on Green Chemistry, including playing a brokering role to identify vendors for research and application needs.
- Support sector or cross-sectoral Green Chemistry initiatives in industry.
- Provide and coordinate technical support including research and development, application and conducting or facilitating product performance testing.
- Provide opportunities for demonstration of Green Chemistry innovations.